to be somewhat higher on balloon records than on kite records for the reason that the kite flight usually follows the morning balloon observation and if a region of especially high winds is found it is likely to be avoided with the kites, or the kite flight delayed for a time.

While a knowledge of the distribution of high winds, as shown in Figure 7, will help in a general way to determine what may be expected in flying, much greater detail is desirable when applied to any particular route, as has been done by Mr. W. R. Gregg and Lieut. J. P. Van Zandt for the transcontinental air mail;[6] but such an analysis is beyond the scope of this paper. In individual cases the aviator who has a definite knowledge of existing winds gained from pilot balloon reports may often avoid strong head winds by flying above or below the customary height or by waiting until midday or later when this is possible.

Winds at high altitudes.—Winds at high altitudes are of very small importance to present day aviation; but during the last few years they have become a matter of considerable interest and speculation as affording a means of flying across the country at tremendous speed. For instance in the *Scientific American*, September, 1922, "Across America in Eight Hours," it is stated that the wind at 7½ miles up always blows from the west, "and maintains an average speed of something like 250 miles per hour."

Such statements are highly exaggerated. Pilot balloons have been sent up daily at a number of places over the United States during the past five years, and the highest velocities ever observed fall considerably short of the 250 miles per hour given as the average speed. During the winter, when the winds are strongest and blow almost continuously from a westerly direction, the average speed is about 100 to 115 miles per hour 6 miles above this region; while in summer the average speed drops to about 35 miles per hour over the southern part of the country; and winds from an easterly quarter occur with increasing frequency from the northern part of the country to the southern.

Both at Broken Arrow and Groesbeck 150 balloons have been followed to the 10-kilometer level (6.2 miles) during the 4-year period. The average speed for the year at that level at Broken Arrow is 74 miles per hour (33 m. p. s.) and at Groesbeck it is 66 miles per hour (29.4 m. p. s.). Twenty-five per cent of all winds observed at the 10-kilometer level at Broken Arrow have an easterly component, while 41 per cent at Groesbeck are easterly. In summer at Groesbeck the easterly component amounts to 66 per cent and the mean direction is northeast.

So it is not simply a matter of going up 6 or 7 miles any time and finding a gale from the west. The aviator who desires to make a record breaking trip by taking advantage of the strong winds aloft should, and generally does, consult the Weather Bureau to find out the odds in his favor.

[6] *The wind factor in flight: An analysis of one year's record of the Air Mail.* MO. WEATHER REV., March, 1923, 51: 111-125.

UPPER AIR OBSERVATIONS AT SEA.

Because of the experimental work being carried on by the U. S. S. *Langley*, it has been impossible to make flights with the Aerograph as no planes or pilots have been available for this work.

On Thursday September 13, 1923, while the *Langley* was en route from Boston, Mass., to Norfolk, Va., and after flying exercises had been carried out, one Vought plane was assigned to make an aerological flight.

At this time the *Langley* was off the Virginia coast, and after the plane had been equipped with the Friez aerograph, the Schneider altigraph, and a Navy pocket altigraph, Lieut. Braxton Rhodes as pilot and Chief Quartermaster Williams as aerological observer, took off from the deck of the *Langley* and made an aerological flight to 15,000 feet.

In ascending to this altitude four separate layers of cloud forms were gone through. Nothing of importance concerning the weather was gained by this flight, the conditions being normal.

As before, it was found that the vibration was too great to expect accurate results from the Friez aerograph, although an entirely new method was used in attaching the instrument, but by experimenting during the flight it was learned that by making minor changes, the effect of vibration will be nearly or completely eliminated.

In the history of upper air observations this is the first time that an aerological flight has been made from the deck of a moving vessel at sea, and while the plane landed at the naval air station, Hampton Roads, Va., it is known, from past experiments, that it could have landed aboard the *Langley* just as it had taken off.

From this flight, then, it can be seen that in the near future, with the development of aircraft carriers, a regular schedule of upper air observations can be carried out while these vessels are at sea, and the results obtained used in compiling data heretofore not obtainable.—*Franklin G. Williams, C. Q. M., U. S. Navy.*

THE ANTICYCLONE OF SEPTEMBER 12-18, 1923.

By ALFRED J. HENRY.

[Weather Bureau, Washington, D. C., October 17, 1923.]

In the previous number of this REVIEW[1] some comment was made upon the appearance of the first pronounced anticyclone of the season in the Canadian Northwest. In this number it is proposed to discuss in like manner the origin and movement of another larger and more enduring anticyclone that completely dominated the weather of eastern United States and Canada September 13-18, 1923.

In reality there were two anticyclones; the first is plotted as track No. VII and the second as track No. VIII of Chart I of this REVIEW. For convenience these will be referred to as the "first" and "second" anticyclone.

[1] Henry, A. J.: The first cool wave of 1923 in the Dakotas and Lake region. MO. WEATHER REV., 51: p. 402.

The barometric situation.—The barometric situation on the 10th was as follows: A trough of low pressure (29.9 inches) stretched from Minnesota south-southwest to Texas and an anticyclone (30.2 inches) covered the Lake region with a second anticyclone (30.2 inches) apparently moving southeastward from the Province of Alberta, attended by a sharp fall in temperature in western Saskatchewan and Assiniboia.

Subsequent development.—The Alberta anticyclone above mentioned advanced to eastern Montana in 24 hours and apparently continued to move in a southeasterly direction, although its identity after the 11th can not easily be distinguished.

On the morning of the 12th a fresh anticyclone (30.4 inches) appeared at Prince Albert, Saskatchewan, a station on the extreme northern limit of the weather map. This anticyclone, which will hereinafter be designated as the second anticyclone and with which we are chiefly concerned, moved rather rapidly southeastward and eastward, crossing the Great Lakes on the 15th and 16th, disappearing off the coast of the Middle Atlantic States on the 18th; it brought frost and freezing temperatures to the northern interior border States and to the interior of New York and northern New England. This anticyclone belongs to the class sometimes referred to by United States Weather Bureau forecasters as "reinforced HIGHS" because of the fact that they descend from the Canadian Northwest directly upon an existing anticyclone which may lie athwart its path. In some cases a very slight fall in barometric pressure can be detected immediately in the rear of the anticyclone which apparently obstructs the path of the second anticyclone, but in many other cases such a fall can not be detected with observations separated by a 12-hour interval. A characteristic of this and other anticyclones of the same class is a tendency toward a rise in the level of the barometer in the central area as the anticyclone passes eastward. An explanation (it may not be the true one), would ascribe the rise in pressure to a strong inflow, mostly aloft, of dense air, the strength of the inflow being a function of the intensity of the cyclone center that immediately preceded the anticyclone.

Central pressure rose to 30.5 inches on the morning of the 16th and the rise was coincident with the disappearance of the cloud layer associated with the central area of the anticyclone, which doubtless prevented nocturnal radiation from cooling the atmosphere in that particular region.

Antecedent conditions.—Returning now to a consideration of the barometric situation as described in a previous paragraph, let us first consider the trough of low pressure. The width of the trough, counting from the 30-inch isobar on each side, ranged from 500 miles in the latitude of Oklahoma to less than 250 miles in Iowa. A weak cyclonic circulation can be detected in northeastern Kansas, but in general the surface winds in the trough were light south to southeast; in the free air, as at the kite stations of Ellendale, N. Dak., Drexel, Nebr., and Broken Arrow, Okla., the southerly surface winds shifted to southwest and west winds at a comparatively low level and the velocity diminished almost to zero. On the extreme west margin of the trough light northwest to north winds prevailed and we recognize at once the condition frequently referred to as a system of opposing winds. Strictly speaking the winds are not opposing, but rather one branch of the system—the north winds—approaches the other at a rather large angle instead of head-on, and being of greater density underruns and displaces the other. Eventually these two systems may unite, or merge with the prevailing west winds at about 4 kilometers. At the top of the warm southerly winds in this particular case and probably in other cases, there is found a region of marked discontinuity in the speed and direction of the wind, the extent of which can not be determined by the use of kites, since the wind speed diminishes to near zero. The southerly winds at each kite station here considered diminished in speed, as just stated, but on the contrary the northerly winds *increased* in speed with increase in altitude.

The contrast in temperature between these two wind systems must be much more pronounced in the cold than in the warm season and in this increase may be found the explanation of the greater driving power of the winter circulation.

The transition from summer to winter.—The change in the weather types begins in late summer or early autumn; it is accomplished not in a steady and uniform march from high to low temperature but rather in a series of steps at irregular intervals. At the conclusion of each step the general mean temperature is several degrees lower than it was at the beginning of the step and when a rise in temperature begins, as it must every few days, it must start from an initial point several degrees lower than was the case previously. The northerly winds being cooler than the southerly penetrate farther and farther to the southward as the season progresses and thus the change from the maximum of summer to the minimum of winter is brought about.

Free air winds in front of the anticyclone.—As just indicated the free air winds on the northwest side of the barometric trough were colder and thus of greater density than those from the opposite quarter. Some details from the kite flights will now be given. On the 10th the maximum velocity of the winds at 4 kilometers above Ellendale was 23.2 m. p. s. (51.9 m. p. h.). At Drexel on the same date, that station being within the barometric trough before referred to, the minimum velocity of the flight, 1.2 meters p. s. (2.7 m. p. h.), was reached at the top of the flight—1,442 meters above the surface at the station.[2] The kites, of course, were not able to ascend above that level. The Drexel station on the 11th came under anticyclonic influences (the first), and the wind direction was N.-NE. up to 1,500 meters (sea level) backing to W.-NW. at 1,536 and continuing in that direction to the top of the flight, 2,048 meters. The maximum velocity, however, was found about 500 meters above the surface, diminishing thence to the top of the flight.

On the 12th the Ellendale station came within the influence of the second anticyclone and the winds were then N.-NW., surface up to 1,000 meters, NW. 1,250 meters to 2,073 meters, then W.-NW. to 2,878 meters, the top of the flight and the maximum velocity, 23.3 m. p. s. was reached at the same level. Drexel on the same date apparently had not come within the influence of the second anticyclone, for we find the winds from the surface to 3 kilometers as being from the W. shifting to W.-NW. at 3,462 meters, then suddenly becoming NW. and so continuing throughout the descent to the surface. The maximum velocity, 28.7 m. p. s. (64.2 m. p. h.), was reached at the top of the flight. The significance of the shift of the wind to the NW. at the top is not clearly apprehended. On the following day when the center of the anticyclone was about 200 miles north of the Drexel station, the winds were NE. in the first 100 meters above the surface, E.-NE. the next 100 meters, then backing to NE. and so continuing up to 604 meters (above the surface). N. at 1,104 meters, N.-NW. at 1,604 meters and W.-NW. at 2,604 meters (surface) and so continuing up to the top of the flight at 3,921 meters (surface). The maximum velocity, 24.5 m. p. s. was reached at that level. From this and other cases the inference may be drawn that anticyclonic circulation of late summer may cease at say a little below 1,000 meters above the surface of the ground.

The temperature of the northerly winds.—When the shift to the north occurs the temperature of the north

[2] The tabular values of free-air conditions, as given by kite flights are referred to sea level as a base. The writer prefers to think of the temperatures referred to the ground as a base and for that reason has indicated in the text whenever altitude above the ground surface at the station is meant.

winds is not much different from that of its immediate surroundings, since it is air *in situ* that first begins to move toward the south. Temperature inversions with altitude may be experienced in air but recently set in motion toward the south, but by far the most pronounced inversions are found in the barometric minima which precede the anticyclone. Some mention of these will be made later. One would naturally expect the temperature of the air column in front of an oncoming anticyclone to be relatively low. At Ellendale on the 11th with the close approach of the anticyclone the kite flight could not be made until the afternoon, thus preventing an accurate comparison with the temperature of the different levels as recorded in the morning hours of the previous day. If, however, we take the levels above 1,500 meters the effect of diurnal variation is quite small and we get the following 24-hour changes:

At 2,000 meters a fall of 7.4° C.
At 3,000 meters a fall of 8.1° C.
At 3,500 meters a fall of 8.1° C.
At 4,000 meters a fall of 8.4° C.

The air column temperatures at Drexel on the same date were about 7° C. lower than on the preceding day, but here, too, an exact comparison is not practicable.

Large temperature inversions in southerly winds.—It is common knowledge that southerly winds in the free air are warm winds. For the dates in question there were rather frequent temperature inversions, the most pronounced were those noted at Ellendale on the 14th and 15th after the anticyclone had passed to the eastward and a new cyclone was approaching from the northwest.

On the 14th, with the cyclone center distant about 700 miles to the northwest, the actual temperature at the surface at Ellendale was 5° C. falling to 4.7° C. 54 meters higher and then rising to 13.5° at 556 meters above the surface; the top of the warm stratum was reached at 2,000 meters above the surface. On the following day with the cyclone center distant but 400 miles surface temperature in a south wind was 7.3° C., at the level 556 meters higher it had risen to 17.4° C. and at 2,000 meters the temperature was still higher than at the surface and the wind had become south-southeast in direct response to the barometric minimum in the northwest. On the next or third day the warm layer had reached the surface and the cyclone center at the same time had reached the meridian of the station. Thus we have an exact value of the rise in temperature in a S.-SW. current, not at the center of the cyclone but at a considerable distance to the southeast and not at the ground surface but at an altitude about 500 meters higher. It is to be noted, moreover, that this warm current was not deflected toward the cyclone center approaching from the northwest until the latter had approached to within 400 miles of Ellendale.

Discontinuities in wind speed and direction.—In this study the fact that the existence of a pronounced discontinuity in the free air can not be determined by the use of kites comes into prominence. Fortunately pilot balloon flights are made twice daily at kite stations. From the reords thus obtained it is possible to visualize the structure of the winds throughout a vertical distance of several kilometers. The morning kite-flight at Broken Arrow, on September 10, came to an end for lack of wind movement within 100 meters or so, of a current of moderate westerly winds (winds from the east) as was disclosed by the pilot balloon run of that morning. A pronounced discontinuity was found at the 2,250 meters level through which the kites were unable to pass. Above this level a current from the East was found having a depth of a little more than 2 kilometers and a maximum velocity of 13 m. p. s. The upper half of this westerly current fell off in velocity to less than 2 m. p. s. at 4,600 meters, where a second discontinuity was found. Above this level a W.-NW. current prevailed up to the 9.5 kilometer level, with a velocity at that level of 25 m. p. s.

In the pilot-balloon run made at 2:57 p. m. (90th Meridian Time) of the same date the discontinuities above mentioned had disappeared and the westerly current apparently had been replaced by one from the S. SE., extending through a vertical height of 3,700 meters above the surface. Above that level the wind backed through N. to NW. and a very deep and moderately strong current from the last-named direction prevailed up to 14 kilometers with the greatest velocity at the 12.5 kilometer level. On the morning of the following day the winds at 4.5 kilometers were W.-NW. becoming NW. at 6.7 kilometers and continuing thence to 13.7 kilometers as a deep W.-NW. current of relatively high velocity. The greatest velocity, 25.5 m. p. s. was found at the top of the run. This wind persisted throughout the 11th and 12th. In order the better to visualize the conditions that were found on the 10th the two pilot balloon runs have been plotted in Figure 1, the morning run at the top and the afternoon run at the bottom. A marked discontinuity in the speed and direction of the wind was disclosed on the 11th in the morning run only to disappear in the afternoon run. Under certain conditions the lower layers of the atmosphere may contain many discontinuities and "near" discontinuities.

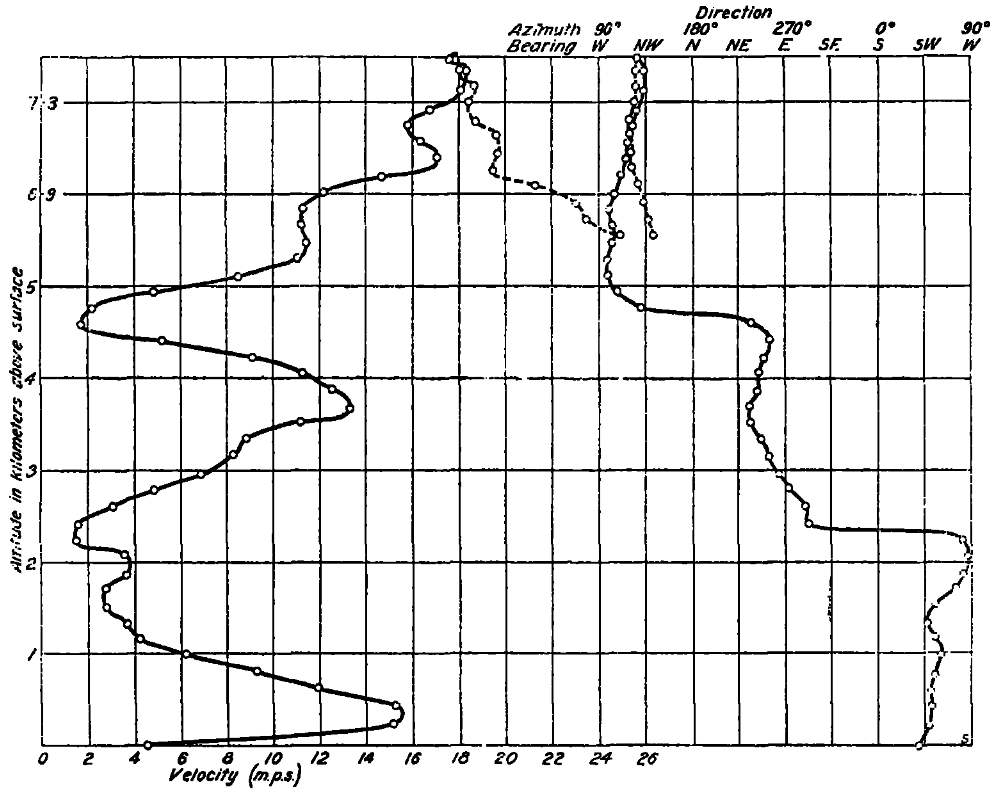
The writer can not but feel that he has only scratched the surface of this interesting problem. It is of course hazardous to draw conclusions from but a few examples but the excellent agreement among those examined leads to the suspicion that they may have been representative of average conditions. With this limitation in mind the following may be presented as the outstanding features of this brief study: (1) The very considerable stratification of the atmosphere as regards wind direction and speed; (2) the shallowness of anticyclonic circulation in late summer; (3) the prevalence of northerly winds far in advance of the anticyclone center at an altitude of 5 or 6 kilometers.

Discussing very briefly the forecasting value of each of these features, it may be said that the stratification of the atmosphere as to wind direction and speed need not be surprising since the temperature and probably the pressure are frequently in that condition. Neither should it occasion surprise to find that the anticyclonic circulation disappears at a relatively small distance above the surface. This is in accord with a belief that has been growing within recent years. Effort should be put forth to determine the elevation at which it disappears on the average of all seasons.

As this paper was being finished a pilot-balloon run was made at Washington, D. C., p. m. of October 18, 1923. This run disclosed a zone of light, variable winds extending to the 6-kilometer level surmounted by a layer of northerly winds having a speed of nearly 20 m. p. s. The run at Aberdeen, Md., at the same time reached a level of 12 kilometers and showed a NNE. wind at that level of 20 m. p. s., thus substantiating the Washington record.

At the time these runs were made Washington was on the eastern margin of a large depression that was centered over the lower Ohio Valley, moving northeastward.

Four days later the Ohio Valley and the Lake region were occupied by a rather strong anticyclone. In the judgment of the writer the northerly winds observed at Washington and Aberdeen can not be considered as foreshadowing the appearance of the anticyclone, as above mentioned. In the case of the northerly winds observed at Broken Arrow on September 10, as hereinbefore mentioned, the anticyclone of that date passed to the eastward rather than to the southward and thus over the Oklahoma station. Later in the season strong anticyclones will probably pass from the Dakotas directly southward to the Gulf of Mexico and thus will afford the opportunity of studying in detail the structure of the atmosphere in these pronounced features of atmospheric cooling.



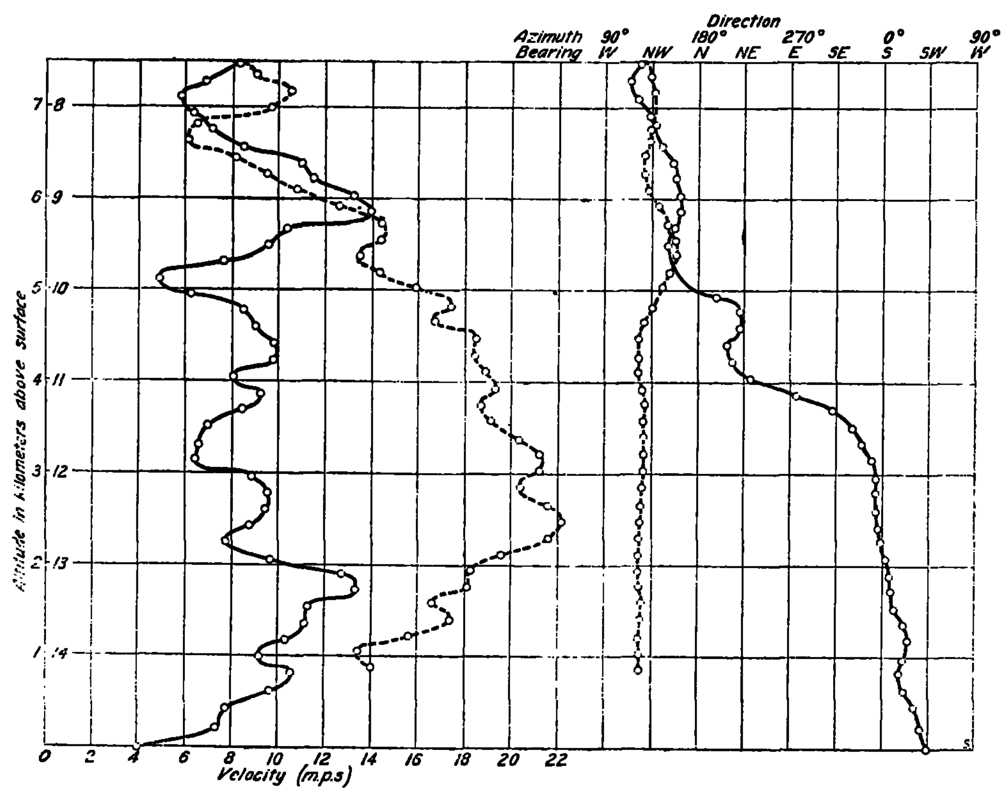


FIG. 1.—Altitude-direction and speed graphs from Broken Arrow, Okla., September 10, 1923. Upper: Morning pilot balloon ascent. Lower: Afternoon ascent.